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ASSEMBLY — 41ST SESSION

TECHNICAL COMMISSION

Agenda Item 33: Other issues to be considered by the Technical Commission

PAVEMENT ASSET - OPTIMISATION OF THE OVERALL LIFECYCLE OF PAVEMENT FOR MASTERING AIRCRAFT OPERATIONS, COST EFFICIENCY AND GHG FOOTPRINT

(Presented by the International Coordinating Council of Aerospace Industries Associations (ICCAIA))

EXECUTIVE SUMMARY

Airfield pavements represent 30 per cent of the initial airport construction investment and up to 40 per cent of annual airport infrastructure maintenance cost. While they are the main airport infrastructure asset needed for take-off, landing and taxiing operations, their contribution to the greenhouse gas (CO_2, NH_4, N_2O) emissions along their entire life cycle, is far from negligible. This paper presents the latest advances in this area and in particular, the recent transition from the semi-empirical pavement design and analysis methods (CBR and PCA) to the layered elastic analysis (LEA). LEA allows pavement to evolve from a curative to predictive approach. This new paradigm, widely used for pavement design and analysis, has been adopted by ICAO in July 2020, as its new pavement rating system (the ACR-PCR).

Nevertheless, it is of paramount importance to further address pavement topics with a holistic view, on which all stakeholders (airports, aircraft manufacturers, airliners, regulators etc.) continue to work towards an optimized airfield pavement for safe and durable operations, with lower cost and lower environmental impact. This virtuous circle would benefit every stakeholder, provided it is well understood and implemented. Full control of pavement management (from raw material production to end-life), would decrease GHG emissions at airport, minimize recurring and non-recurring cost (through controlled pavement evaluation and maintenance), and optimize allowable aircraft operational weights at airports.

Strategic Objectives:	This working paper relates to the Safety and Environment Strategic Objectives.
Financial implications:	None
References:	Annex 14 — *Aerodromes*, Volume 1 — *Aerodrome Design and Operations* Doc 9157, *Aerodrome Design Manual,* Part 3 – *Pavements* –, Third edition, 2022

1. INTRODUCTION

1.1 The last two decades have seen a major change in the pavement design and analysis methodology. the semi-empirical California Bearing Ratio (CBR) design procedure has been gradually replaced by the layered elastic analysis (LEA) whose features allow a more accurate pavement design (optimised pavement material characteristics and thicknesses), to monitor the remaining pavement structural life (thus anticipating maintenance and major rehabilitation), and to better manage the aircraft allowable weight and frequencies at airport.

1.2 LEA became the core principle of the ICAO ACR-PCR system, which became effective in July 2020, with a full applicability in November 2024.

1.3 The method allows consideration of the full effects of landing gear configuration as well as the improved performance of new-generation pavement materials, thus alleviating the conservatism of the former system (ACN-PCN), which rested on the CBR procedure for flexible pavements (70 per cent of runways / 50 per cent of taxiways worldwide).

1.4 Consequently, the method enables an optimized use of existing and future pavements; it provides also a consistent damage-based approach, which allow to better assess the impact of overload operations and improve the pavement life predictability.

2. DISCUSSION

Pavement

2.1 Airfield pavement maintenance or major rehabilitation is often reactive, based on failure. This experience-based approach is hazardous, cost consuming and responsible for many operational disruptions.

2.2 The new ICAO pavement rating system (Amendment 15 of the Annex 14: the aircraft/pavement classification rating ACR/PCR), rests on the principle of additivity of the damage produced by every individual aircraft analyzed in a mix, thus resulting in a cumulative pavement damage. Consequently, there is not one single aircraft type that is identified as contributing to pavement damage, but the combination of all aircraft composing a mix, which produces a total damage, considering the intrinsic characteristics of each aircraft.

2.3 This combination results in a damage curve, expressing the cumulative damage factor (CDF) of a pavement cross-section subjected to the analyzed traffic mix. The cumulative damage factor (CDF) is defined as the amount of the structural fatigue life of a pavement that has been used up. It is expressed as the ratio of applied load repetitions to allowable load repetitions to failure. By convention, a new pavement construction has a CDF equal to zero, while a theoretical end-life pavement has a CDF equal to 1.0.

2.4 The combination of all aircraft composing the mix results in a pavement damage curve with a maximum value representing the maximum damage. The contribution of each aircraft composing a mix to the maximum damage is then determined precisely at this location (critical offset) since this is the most stressed pavement location. This principle allows monitoring the theoretical pavement residual life at any time, and anticipate failure with appropriate routine maintenance.

2.5 Any change of the reference traffic mix has a direct effect on the CDF, thus on the pavement design life. As an example, the Covid-19 pandemic has theoretically produced an increase of the world airfield pavement-life between 5 and 10 per cent (considering that the short-medium range aircraft segment will recover in 2023 and the long-haul segment in 2025 as compared to yr. 2019).

2.6 This inability to use LEA disadvantages every stakeholder:

a) States using empirical methods have little knowledge of their pavement mechanical properties, thickness and bearing capacity, making them unable to adopt innovative pavement predictability methods. As a result, those States and their airports are continuously deal with costly curative pavement repairs, are not able to properly manage routine maintenance and report erroneous pavement ratings with consequential inaccurate aircraft weight or frequency limitations;

b) airlines operators are penalized through under-estimated PCNs leading to weight limitations;

c) airports provision more CAPEX for infrastructure than is necessary (a well-established pavement maintenance plan cost less than non-mastered maintenance after unexpected failure); and

d) passengers may experience discomfort due to bumpy runways or delays due to unexpected pavement repairs.

2.7 Such a situation could be addressed through information, training, capacity building and associated tools.

2.8 The intensive use of this game-changing approach (from curative to predictive) will benefit for both in-service and new-constructed pavements:

a) in service pavement designed with the former semi-empirical design procedure, thus, theoretically over-designed, will be evaluated for the ACR-PCR implementation with a resulting extended design life; and

b) new constructed pavement, designed with the LEA, will require less pavement thickness than it was required with the older design methods.

2.9 Both cases will contribute to reduce the GHG emissions for the ground sequence, thus contributing to aviation decarbonisation objectives. Indeed, LEA and associated techniques allow pavement monitoring, predictive maintenance, usage optimization, and consequently, reduces GHG produced along pavement life cycle.

Aircraft

2.10 The LEA approach could be further improved with the NEXT GEN aircraft through an optimized main landing gear footprint, which would better distribute aircraft weight on ground with regard to the pavement design parameters. The optimisation should consider the following parameters without jeopardizing aircraft performance and the mission for which the aircraft is designed:

a) individual wheel load (function of aircraft weight, center of gravity and number of main landing gear wheels);

b) main gear leg geometry (the higher the wheel spacing, the lower the pavement damage: close wheels increase load overlap hence pavement damage);

c) internal tire inflation pressure which impact is limited to pavement surface due to shear stresses; and

d) main landing gear overall track.

2.11 All of these parameters are combined in the calculation of a unique number, termed the ACR (The aircraft component of the ACR-PCR protocol), which is numerically defined as twice a standard derived single wheel load (DSWL) expressed in hundreds of kilograms. The DSWL is a single wheel load (with a standard contact pressure of 1.5 MPa), that is equivalent (according to a defined criterion) to the aircraft on a given pavement structure. The ACR is then a real indicator of aircraft damaging effect on airport infrastructure, thus, it gives a relative view of the aircraft contribution rate to the GHG emissions along pavement life cycle.

2.12 With the ACR-PCR implementation phase (2020-2024), requiring airport pavement evaluation, there is a unique opportunity to establish a starting point of the world airfield-pavement heritage. This first step will serve airport PCR determination and publication, and will provide each airport with the remaining pavement structural life, with the associated maintenance plan to extend initial design life. Overall, the procedure should cost less than it will return, with reduced CAPEX investment and GHG emission reduction in the medium-long term. Furthermore, the combination of the ACR-PCR and any traffic data monitoring system could be incorporated in airport Pavement Management System (PMS), allowing an ultimate pavement use optimization, and to anticipate any damage (or increased pavement life span) which would be produced by unexpected traffic changes (higher annual departure rate or sudden traffic slow down).

Operations

2.13 The ACR-PCR system brings several benefits to the industry, such as the optimized use of pavements and consistency between pavement design and aircraft admissibility assessment. While the ACR calculation procedure is fully prescribed and straightforward, the PCR determination process is inherently more complex and relies on multiple skills related to geotechnics, pavement materials, pavement damage modelling, and a sound knowledge of the aircraft impact on pavements.

2.14 In order to take full advantage of this new system, airports should determine their PCR as accurately as possible, which requires a careful collection and analysis of the required aircraft traffic and pavement structure data. The PCR calculation relies on a pavement damage model whose selection can drastically influence the outcome. As there is no universal damage model, it is important to understand their assumptions and check their adequacy to the specific PCR calculation context. In particular, one should ensure that the damage model implemented in a PCR calculation software is consistent with the design parameters before using it. Failing that, the PCR would be incorrectly assessed leading to operational constraints. Under-estimated PCR would lead to aircraft operating weight limitation at best or aircraft refusal in the worst case, thus a loss of airport revenues and a pavement not used up to its optimum structural capacity. Conversely, over-rated PCR would lead to an increase of overload operations and a pavement design-life reduction. The extra revenues from operations would be negatively balanced by the resulting pavement damage.

3. CONCLUSION

3.1 ICCAIA congratulates ICAO for all efforts achieved over the past two decades on airport pavement asset related matters and encourages further actions toward the optimization of airfield pavement life cycle in a holistic manner, considering economic, operational and environmental benefits.

3.2 The global approach related to airport pavement asset, should involve all stakeholders to enhance aircraft operating weights, reduce airport cost and invest through predictive maintenance, and bring significant GHG reduction along pavement life cycle.

3.3 The new advanced models should gradually replace the past semi-empirical methods with the ACR-PCR implementation phase. ACR-PCR incorporation within any PMS will then allow airport cost reduction in all pavement phases (design, construction, evaluation, maintenance, operations etc.). As a global system, end users could benefit from these reductions and even more with the next generation aircraft, which will be more pavement friendly with optimized main landing gear footprint.

3.4 ICCAIA encourages States to adopt the new approaches described in this paper, and urges ICAO to continue to support efforts to provide training, best practices and information, with the support of industry stakeholders and States who can provide practical experience.

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